A decade of experience with dorsalis pedis artery bypass: Analysis of outcome in more than 1000 cases

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Objective: **The purpose of this study was to review our experience over the last decade with the dorsalis pedis bypass for ischemic limb salvage in patients with diabetes mellitus.**

Methods: **The study was a retrospective analysis of a computerized vascular registry and chart review. From January 10, 1990 to January 11, 2000, 1032 bypasses to the dorsalis pedis artery were performed in 865 patients (27.6% of the 3731 lower extremity arterial bypass procedures performed in that time period). Five hundred ninety-seven patients (69%) were male, with a mean age of 66.8 years. Ninety-two percent had diabetes mellitus. All procedures were done for limb salvage. Conduits included 317 nonreversed saphenous vein (30.7%), 273 in situ (26.4%), 235 reversed vein (22.8%), 170 arm vein (16.5%), 35 other vein (3.4%), and two polytetrafluoroethylene (0.2%) grafts. The inflow arteries were as follows: 294 common femoral (28.5%), 550 popliteal (53.2%), 114 superficial femoral (11%), and 74 other (7.2%).**

Results: **The mortality rate within 1 month of surgery was 0.9%, and 42 grafts (4.2%) failed in the same interval, although 13 were successfully revised. In a follow-up period that ranged from 1 to 120 months (mean, 23.6 months), primary patency, secondary patency, limb salvage, and patient survival rates were 56.8%, 62.7%, 78.2%, and 48.6%, respectively at 5 years and 37.7%, 41.7%, 57.7%, and 23.8% at 10 years. Both polytetrafluoroethylene grafts failed in less than 1 year. Primary graft patency was worse in female patients (46.5% female versus 61.6% male at 5 years; $P < .009$) but better in patients with diabetes (65.9% diabetes mellitus versus 56.3% non-diabetes mellitus at 4 years; $P < .04$). Saphenous vein grafts performed better than all other conduits with a secondary patency rate of 67.6% versus 46.3% at 5 years ($P < .0001$). Multivariate analysis showed that length of stay greater than 10 days and dorsalis pedis bypass for the surgical indication of previous graft occlusion were independently predictive of worse graft patency at 1 year and use of saphenous vein as conduit was predictive of better patency.**

Conclusion: **Dorsalis pedis bypass is durable with a high likelihood of ischemic foot salvage over many years. Saphenous vein is the preferred conduit when available. Short vein grafts from distal inflow sites are possible in more than 50% of cases. These results justify the routine use of pedal arterial reconstruction for patients with diabetes with ischemic foot complications. (J Vasc Surg 2003;37:307-15.)**

Dorsalis pedis (DP) artery bypass is particularly well suited for the treatment of ischemic foot complications in patients with diabetes mellitus because of the characteristic pattern of atherosclerosis seen in these patients.[1] We have previously reported our results with DP bypass in nearly 400 patients[2] and also its applicability in patients with ischemia complicated by foot infection[3] and in healing ischemic heel ulcers.[4] In the last 10 years, DP bypass has been the single most commonly performed lower extremity arterial reconstruction in our practice, comprising nearly 30% of all arterial reconstructions performed.

In spite of our satisfaction with this procedure, some investigators continue to prefer more traditional popliteal and tibial arterial reconstructions.[5-8] The purpose of this study was to review our ongoing experience, now exceeding 1000 procedures, with follow-up extending to 10 years, and to reassess durability, limb salvage, and patient factors that may impact results.

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MATERIALS AND METHODS

Demographic data, indications for surgery, comorbid conditions, specific details about the surgical procedure, complications, and outcome at discharge and during the follow-up period were all prospectively entered into our vascular surgery database. The database was retrospectively queried for this study. All data are presented in accordance with the revised reporting standards of the Joint Council of the Society for Vascular Surgery and the American Association of Vascular Surgery.[9] Grafts were considered patent if a palpable pulse was present over the graft at the level of the dorsal foot. Limb salvage was defined as preservation of enough of the foot to allow ambulation of the patient without the need for a limb prosthesis and included feet requiring toe, ray, or transmetatarsal amputations or partial or complete calcaneous resections[10,11] after pedal bypass. Syme's and Chopart's amputations were not performed in

this patient population. Death during the follow-up period was determined from queries to the Social Security Death Index. After discharge, patients were followed at regular intervals, usually every 3 months during the first year, every 6 months in the second year, and annually thereafter. Follow-up was more frequent in patients with open wounds and after repeat surgical procedures, such as graft revisions or bypasses on the other limb. Graft patency was determined and recorded by the attending surgeon. In the later years of the study, many grafts, particularly arm veins, were followed with duplex ultrasonography, although this was not done routinely. When the registry contained incomplete follow-up information, patient charts were reviewed or patients were contacted by phone to determine the current status of their pedal graft and foot.

Statistics were performed with the aid of Statview 5.0 software (SAS Institute, Inc, Cary, NC). Categoric variables were compared with the χ^2 test, and continuous variables with the Student t test. Factors found to be significant in univariate analysis were then studied in multivariate logistic regression. Independent variables were assumed to be significant if the Wald test returned a P value of less than .05. Survival rates were calculated with the Kaplan-Meier product-limit method. The Mantel-Cox log-rank test was used to compare survival curves among different groups.

Diagnosis and surgical technique. Our approach to DP bypass has been described previously.[12] We continue to rely on comprehensive intraarterial digital subtraction angiography[13] for imaging of the circulation from the renal arteries to the base of the toes in all patients with limb ischemia. Proper imaging of the foot vessels requires views in two planes, usually anteroposterior and lateral, to fully appreciate the quality of the DP artery and its potential use as an outflow target artery. Magnetic resonance angiography was used infrequently in those patients unable to have contrast because of allergies or severe renal insufficiency. "Blind" exploration of a DP artery, not seen on angiography but thought to be patent on the basis of an audible Doppler signal heard in the foot, was performed when appropriate, although this was done much less frequently in the later years of this study because of improvements in radiographic equipment and the experience of our radiologists in imaging foot vessels.

The decision to perform a DP bypass is made on the basis of anatomic and clinical factors. Our preference is to restore a palpable foot pulse when possible in patients with diabetes with any tissue loss on the basis of our observations that the endpoint most reliably leads to healing and foot salvage in the milieu of the compromised biology of the ischemic diabetic foot. If no more proximal outflow target artery will achieve that goal, we will preferentially bypass to the DP artery. In situations of rest pain without tissue loss, the DP artery was chosen as the outflow target vessel when it was the best quality vessel for bypass or the only available outflow vessel as determined on the arteriogram. In circumstances where a femoral-popliteal or tibial arterial bypass would restore a palpable foot pulse and tissue loss was the indication, DP bypass was not performed. In cases of tissue loss or gangrene, DP bypass was often chosen in preference to a patent peroneal artery. Bypasses to the peroneal artery were performed in preference to the DP artery when the DP artery was a poorer quality vessel on the arteriogram or when the vein conduit available was of inadequate length to reach the DP artery. DP bypass was avoided in cases of severe dorsal foot infection and when the indication for surgery was claudication.

Saphenous vein grafts were harvested or exposed through open incisions. We believe this is the simplest and most expedient approach and best identifies potentially diseased, narrowed, or poor-quality conduit. Minimization of serious wound complications requires the avoidance of skin flaps during exposure or the excision of inadvertent flaps before closure. Control of preexisting infection, meticulous hemostasis, and wound closure without excessive tension are other important principles.

Our strategy[14] is designed to simplify the procedure and minimize the use of prosthetic grafts. Briefly, the principles include the use of distal inflow sites and short, translocated, saphenous vein grafts whenever possible. When bypasses originated from the common femoral artery and the saphenous vein was intact, veins were left in situ. Most in situ vein grafts were prepared with an angioscope and pump irrigation system[15,16] inserted into the proximal end of the vein graft with a long flexible valvulotome[17] inserted from the distal end before completion of the anastomoses. Use of a pump irrigation system during angioscopy improved clarity and reduced the time of the study and the volume of crystalloid infused.

When saphenous vein was unavailable or unusable, our first choice for alternative vein conduit was arm vein.[18] When arm veins were not available, lesser saphenous vein was used if the caliber and quality was adequate for bypass. Composite grafts comprised of different vein segments also were occasionally used. The quality of arm and composite vein conduits was also determined with angioscopy.[19] When vein was limited, every effort was made to originate the graft from a distal inflow site even if the superficial femoral artery had some disease as long as it was not believed to be hemodynamically significant. In a few cases, a simultaneous femoral popliteal bypass with a prosthetic graft and a popliteal to DP bypass with vein were constructed in sequence. Previous aortofemoral or iliofemoral reconstructions were also used for inflow for some patients.

Exposure of the DP artery is accomplished with a longitudinal foot incision, placed directly over the Doppler signal of the artery on the dorsal foot. This is generally slightly lateral to the extensor hallucis longus tendon. The artery may occasionally be in a much more lateral location, underscoring the importance of carefully examining the preoperative arteriogram and using the Doppler to precisely locate the artery before making the incision. When in situ vein grafts are performed, the graft is tunneled proximally to and never through the resulting skin bridge between the parallel foot incisions required to expose the artery and dorsal foot extension of the saphenous vein. In

Table I. Outflow target arteries in 3731 infrainguinal arterial bypass procedures performed from 1990 to 2000

	No. of arteries
Above-knee popliteal	415
Below-knee popliteal	508
Anterior tibial	486
Posterior tibial	557
Peroneal	349
Plantar	112
DP	1032
Tibial-peroneal trunk	71
Previous graft	129
Other	72
Total	3731

Table II. Clinical characteristics and surgical indications for patients undergoing DP bypass

	No. of patients
Demographics	
Age (mean; y)	66.8
Male gender	597 (69.10%)
Diabetes mellitus	794 (91.90%)
Hypertension	534 (61.80%)
CAD	405 (46.90%)
Prior MI	259 (30.00%)
CHF	195 (22.60%)
CABG	183 (21.20%)
Creatinine > 2 mg/dL	144 (16.70%)
Dialysis	97 (11.20%)
Current smoker	94 (10.90%)
Indications	
Nonhealing ulcer	809 (78.40%)
Gangrene	380 (36.80%)
Infection	302 (29.30%)
Rest pain	226 (21.90%)
Failing bypass graft	34 (3.30%)

CAD, Coronary artery disease; *MI*, myocardial infarction; *CHF*, congestive heart failure; *CABG*, coronary artery bypass grafting.

our experience, foot wounds can be closed primarily, without the use of advancement or rotational flaps, but must be meticulous, avoiding excessive tension. A single layer of a 4-0 or 5-0 absorbable subcuticular suture or a simple interrupted skin suture is usually adequate. Completion arteriography is rarely performed in our practice. We have previously shown[20] that most technical failures in our procedures occur as a result of problems with the conduit, which are best avoided in our experience with the use of angioscopy in preparation of the vein.

After surgery, patients are placed on aspirin 81 mg a day indefinitely and 5000 units of subcutaneous injections of unfractionated heparin every 12 hours until discharge. In our experience, many wound problems start as a result of significant leg edema, which nearly always accompanies DP bypass. Reduction of postoperative edema is therefore critical in reduction of wound complications. Most patients are restricted from weight bearing on the foot for 2 to 7 days or longer, depending on how well foot wounds are healing and where other ulcers are located on the foot. Resumption of ambulation should be gradual and may require the use of partial weight bearing on crutches or a walker and the use of open-toe postoperative sandals until the foot is healed. The leg should be elevated frequently in the first few weeks to reduce edema. Elastic wraps are often helpful. In spite of these measures, many foot and leg wounds will have some difficulties with healing. Minor skin dehiscence not involving the graft is common and usually responds to conservative measures, such as local dressing care, elastic compression, and restriction of weight bearing. Serious wound problems, including infection with graft exposure, occasionally occur and may require more complex treatment, such as myocutaneous free tissue transfer and skin grafting.

RESULTS

From January 1990 through January 2000, 1032 bypasses to the DP artery were performed in 864 patients. This comprised 27.6% of the 3731 infrainguinal arterial reconstructions performed in that time period (Table I). Patient characteristics are shown in Table II. The mean age was 66.8 years, and 70% of the patients were male. More than 90% had diabetes mellitus. Hypertension and coronary artery disease were present in most patients. Nearly 17% had some degree of renal insufficiency, and 11% were undergoing dialysis at the time of surgery.

The indications for surgery are also listed in Table II. All operations were performed for limb-threatening ischemia or to salvage a failing bypass graft. The most common indication was a nonhealing ischemic foot ulcer. Thirty percent of patients had foot infection in addition to ischemia.

All but two procedures were performed with autologous vein. The types of conduit and inflow arteries are listed in Table III. Seven patients had a DP bypass performed distal to a more proximal prosthetic bypass, including two aortofemoral and two iliofemoral bypasses done previously, two femoral popliteal bypasses done simultaneously, and one other bypass in which the exact configuration was unknown. The most commonly performed procedure was a popliteal to DP arterial bypass with nonreversed saphenous vein. In situ vein grafts were performed in approximately 27% of cases. Alternative vein conduits were necessary in approximately 20%, of which most were arm vein grafts.

Ten deaths (0.97%) occurred within 30 days of surgery. Forty-three of 1032 grafts (4.2%) failed within 30 days. Thirty-one patients (3.0%) had symptomatic myocardial infarction or acute congestive heart failure. The incidence rate of clinically "silent" myocardial infarction was unknown because routine cardiac enzymes were not drawn. Three patients each had acute strokes and acute renal failure. Severe limb-threatening postoperative wound infections occurred in 21 extremities (2.0%), two of which resulted in graft infections and loss of the graft and limb. Less severe wound infections occurred more frequently. The precise number could not be determined from available data in the database. Sixty-eight patients (6.6%) under-

Table III. Conduits and inflow arteries

	No. of patients
Conduit	
Nonreversed saphenous	317 (30.70%)
In situ saphenous	273 (26.40%)
Reversed saphenous	235 (22.80%)
Arm vein	170 (16.50%)
Composite vein	25 (2.40%)
Lesser sphenous	10 (1.00%)
PTFE	2 (0.20%)
Inflow artery	
Below-knee popliteal	426 (41.30%)
Common femoral	294 (28.50%)
Above-knee popliteal	124 (12.00%)
Superficial femoral	114 (11.00%)
Vein graft	49 (4.70%)
Prosthetic graft	7 (0.70%)
Tibial artery	6 (0.60%)
Iliac artery	6 (0.60%)
Deep femoral artery	6 (0.60%)

PTFE, Polytetrafluoroethylene.

went unexpected early reoperation for graft thrombosis, postoperative bleeding, or infection. Thirteen of 42 perioperative graft thromboses were successfully revised. Nineteen could not be revised and resulted in eventual major amputation, and 10 additional failed and unrevised grafts did not result in loss of the foot. In the follow-up period, which extended from 1 to 120 months (mean, 23.6 months), primary patency, secondary patency, and limb-salvage were 56.8%, 62.7%, and 78.2% at 5 years and 37.7%, 41.7%, and 57.7%, at 10 years. Patient survival rates were 48.6% and 23.8% at 5 and 10 years, respectively, and did not differ significantly between male and female patients. The primary graft patency rate was 46.4% for female patients versus 61.6% for male patients at 5 years ($P < .009$). Patients with diabetes faired better than patients without diabetes. The 5-year secondary patency rate for patients with diabetes was 65.9% versus 56.3% for patients without diabetes at 4 years ($P < .04$). Saphenous vein grafts performed better than all other conduits, with a secondary patency rate of 67.6% versus 46.3% at 5 years ($P < .0001$). These results are summarized in Figs 1 to 4. Univariate analysis (Table IV) identified five of 31 clinical factors (presence of ulcer, sepsis, graft occlusion as the indication for DP bypass, revision of the graft, use of saphenous vein as conduit, and length of stay) that had a significant effect on the likelihood of graft patency at 1 year after surgery. On multivariate analysis, however, only increased length of stay and graft occlusion as the indication for DP bypass were independently predictive of worse graft patency, and the use of saphenous vein as the conduit was predictive of better graft patency (Table V).

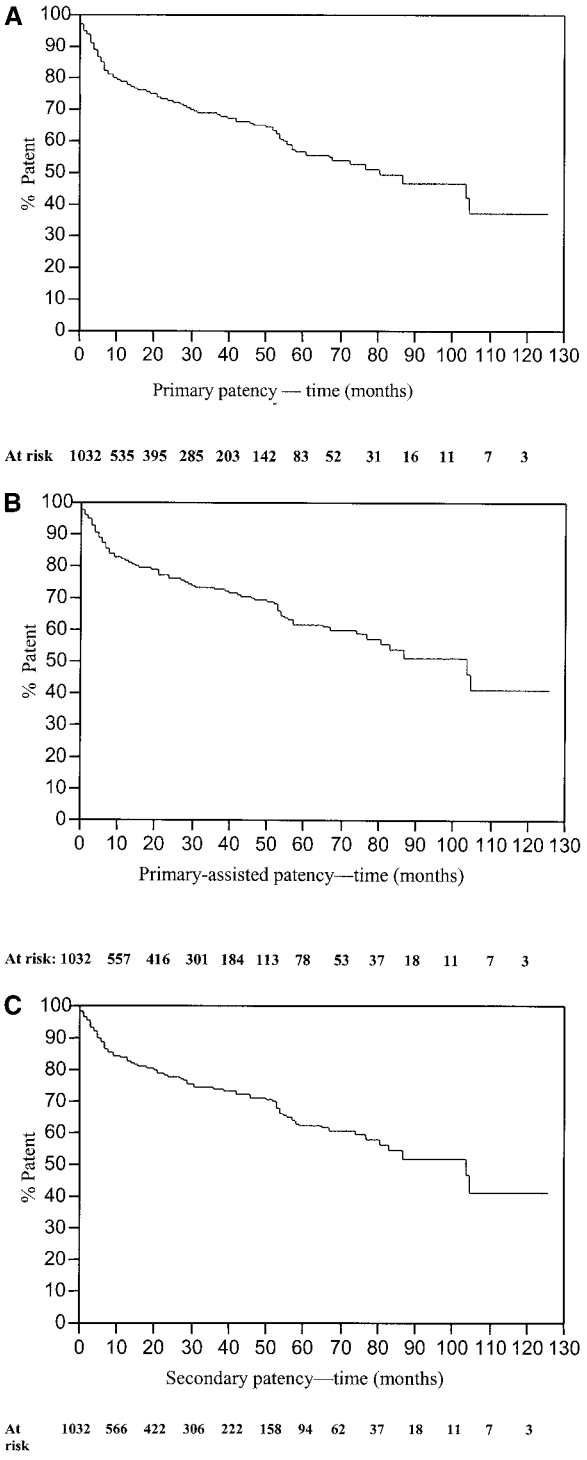

Fig 1. Primary **(A)**, assisted primary **(B)**, and secondary **(C)** patency rates of all DP bypass grafts. Standard error was less than 10% at all time intervals.

DISCUSSION

This study shows that DP bypass for foot ischemia in patients with diabetes mellitus is a safe, effective, and durable procedure. Graft patency and limb salvage rates are comparable with more proximal infrainguinal arterial reconstructions and when performed with saphenous vein have excellent durability with patency for 10 years or longer

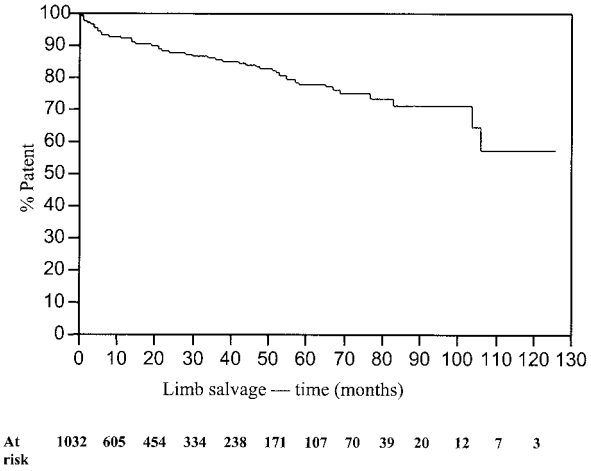

Fig 2. Limb salvage for all DP bypasses. Standard error was less than 10% at all time intervals.

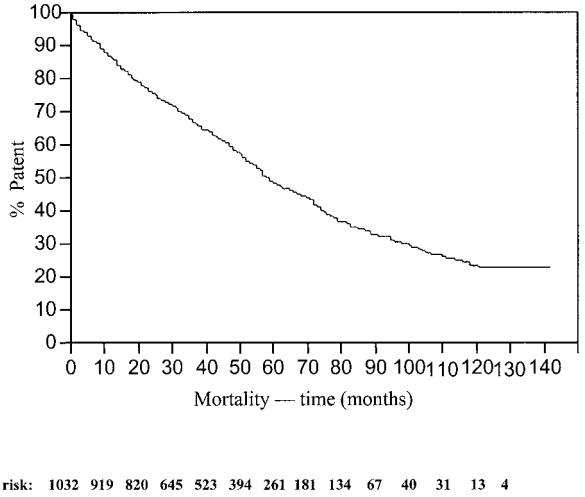

Fig 3. Patient mortality rate for all DP bypass grafts. Standard error was less than 10% at all time intervals.

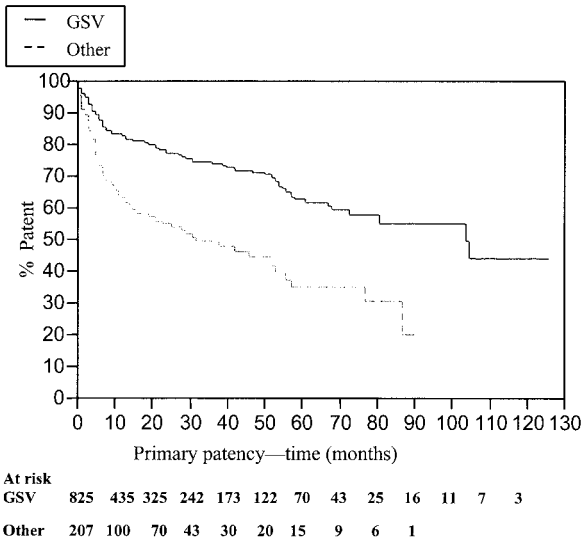

Fig 4. Primary patency rate of greater saphenous vein *(GSV)* versus all other conduits. Difference is significant ($P < .0001$). Standard error was less than 10% at all time intervals.

in some patients. Pedal bypass is well suited to the anatomic pattern of atherosclerosis most commonly seen in patients with diabetes mellitus (tibial/peroneal artery occlusion, minimal involvement of the aortoiliac segment and superficial femoral artery, and sparing of the foot arteries especially the DP artery). For many patients, it may be the only outflow target artery available for bypass and should always be included in the preoperative arteriogram.

Although pedal bypass represents the most extreme form of distal arterial reconstruction, it need not be a technical tour de force. Indeed our enthusiasm and liberal use of pedal bypass in more than 1000 procedures is predicated not only on its efficacy but also its simplicity. The relatively superficial location of the DP artery makes it easily accessible—an advantage making anastomosis to "good" arteries straightforward and those to "bad" arteries (calcified, small caliber, etc) easier. Moreover, the usual pattern of atherosclerosis seen in diabetes makes it possible to use distal inflow, usually at the popliteal artery, more than 50% of the time (53.3% in this study). The advantages of a distally based inflow procedure cannot be overemphasized. It requires less vein conduit, allows the surgeon the opportunity to perform the procedure with the best segment of conduit, and avoids groin dissections in obese patients and lower leg dissections in patients with venous stasis problems or edema. Most importantly, as shown in several reports,[21-23] these advantages do not come with the price of reduced long-term patency from progression of superficial femoral arterial disease. The fact that all but two pedal bypasses were performed with vein grafts shows that if an aggressive effort is made, especially when combined with use of distal inflow arteries, usage of prosthetic grafts can be avoided for most if not all pedal bypasses. The best results can be expected when saphenous vein is used as a conduit, but even alternative vein conduits, most of which were arm vein grafts in this study, are preferable because they performed far better than the expected performance of prosthetic grafts to this level.[24] Preparation of alternative conduits can be challenging but in our experience is aided by the use of angioscopy, which has also proven useful in preparation of in situ saphenous grafts.

These results provide further evidence against the existence of "small vessel disease."[25] DP bypass grafts could neither remain patent nor heal ischemic foot ulcers if the microcirculation was occluded. Although refuted in anatomic,[1,26] physiologic,[1,27,28] and clinical studies,[29] including this report, this antiquated concept persists to this day and continues to result in amputations being performed unnecessarily for foot ischemia. No patient with diabetes and foot ischemia should be considered to have an unsal-

Table IV. Results of univariate analysis of factors influencing graft patency at 1 year after DP bypass

Clinical factor	P *value*
Gender	.426
Diabetes mellitus	.988
Neuropathy	.161
Tobacco use	.380
CAD	.404
CHF	.375
Angina	.486
HTN	.398
Arrythmia	.724
Previous MI	.115
CABG	.786
Previous PTCA	.162
Renal dz	.147
Creatinine > 2 mg/dL	.065
HD	.138
CAPD	.270
Stroke	.083
Any limb ischemia	.850
Ulcer	.024 (<.05)*
Gangrene	.308
Infection	.093
Sepsis	.030 (<.05)*
Abscess	.958
Rest pain	.661
Claudication	.998
Failing graft	.444
Bypass for occluded graft	.000 (<.0001)*
Revised graft	.000 (<.0001)*
Greater saphenous vein	.000 (<.0001)*
Age	.061
Length of stay > 10 days	.000 (<.0001)*

*Significant variables.
CAD, Coronary artery disease; *CHF*, congestive heart failure; *HTN*, hypertension; *MI*, myocardial infarction; *CABG*, coronary artery bypass grafting; *PTCA*, percutaneous transluminal coronary angioplasty; *dz*, disease; *HD*, hemodialysis; *CAPD*, peritoneal dialysis.

Table V. Results of multivariate analysis of variables independently affecting graft patency at 1 year

	Wald test (P *value*)	*Odds ratio*	*95% CI*
Length of stay > 10 d	.0001	0.95	0.93-0.98
Bypass for graft occlusion	<.05	0.38	0.17-0.89
Greater saphenous vein	<.005	1.82	1.25-2.65

vageable condition and undergo amputation on the basis of the diagnosis of small vessel occlusive disease alone.

The low perioperative mortality rate and clinical cardiac morbidity rate refute the finding that diabetes is a risk factor for perioperative cardiac morbidity.[30,31] Although the incidence rate of myocardial infarction is probably underestimated because of the lack of routine postoperative cardiac enzyme determination in this study, the perioperative death and clinically apparent cardiac complications rates were low. Our results are consistent with the findings of Axelrod et al[32] and our larger study that analyzed outcomes of more than 6000 major arterial reconstructions, where diabetes was not found to be an independent risk factor for early cardiac complications or death.[33] Moreover, this report adds further support to the concept that diabetes alone does not portend a worse outcome for arterial reconstructive surgery.[34-38] Patients with diabetes actually had better graft patency and limb salvage rates in this study, and diabetes was not predictive reduced patency in multivariate analysis. We were surprised to find that graft patency at 5 years was worse in women. Previous studies[39,40] have concluded that women do as well as men with lower extremity bypass; however, Magnant et al[41] found that female gender was predictive of lower graft patency. They postulated that smaller caliber arteries or vein grafts may have caused worse patency rates in women, although they had no specific data to support this possibility. We likewise have no data on any comparative differences in the size of arteries in men and women that may have existed. Moreover, although multivariate analysis at 1 and 5 years showed a trend suggesting male gender was associated with better patency with odds ratios of 1.16 and 1.2, respectively, this result did not reach statistical significance ($P = .39$ and .48). We cannot fully explain our results and continue to believe that the expectations for women with DP bypass should be no different than for men.

We recognize that many groups have reported equivalent results in limb salvage, with much lower rates of usage

of pedal arterial reconstruction, and in two studies, peroneal artery grafts performed as well as pedal grafts for patients with similar indications.[5,6] In our practice, DP bypass appeared to be the principal factor resulting in a decrease in the number of both major and minor amputations performed for ischemia over a 10-year period.[42] The advantage of DP bypass seems intuitive in that restoration of arterial perfusion to the ischemic diabetic foot is direct, in close proximity to the ischemic lesion and not dependent on terminal branches or collaterals. More importantly, when given equal consideration to popliteal or crural outflow targets, DP bypass adds another potential bypass option, resulting in the ability to perform a limb-sparing arterial reconstruction in a group of patients previously treated only with amputation. On the basis of the results of this study, DP bypass will continue to be a mainstay in our treatment of ischemic foot salvage in patients with diabetes mellitus.

In summary, pedal arterial reconstruction has proven to be a safe, simple, durable, and highly effective procedure in a large patient cohort with advanced limb ischemia of which more than 90% had diabetes mellitus. Pedal bypass is particularly well suited for ischemic foot salvage in these patients because of the pattern of atherosclerosis most commonly seen. The use of short vein grafts from distal inflow sites can simplify the procedure and is possible in most patients. DP bypass should be in the armamentarium of all vascular surgeons treating limb ischemia in patients with diabetes mellitus.

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DISCUSSION

Dr Kevin G. Burnand (London, United Kingdom). One of the results that you have not given us is how many toes and forefeet you had to amputate. Have you done an analysis on forefoot amputation or digital amputation? Would that be an independent risk factor in terms of outcome?

Dr Frank B. Pomposelli. I do not have precise data, although I suspect that there is actually a large number of patients who had some sort of a minor foot amputation in the study, probably about 40% to 50%.

Transmetatarsal amputation has not been a risk factor for pedal graft failure. They actually will heal quite well, and the graft will remain patent.

Dr George Andros (Encino, Calif). I am absolutely drunk with delight. This is a cornucopia of information. I think it is probably the most important diabetic vascular paper in the 30-plus years that I have been coming here. It is just an amazing series, Frank.

A few questions. Do you rely on MRA? We still do angios. MRA has been talked about a lot. Would you comment?

We still probably do more bypasses to the posterior circulation, and we are seeing an awful lot of heel ulcers and would actually go to the heel, plantar, or posterior tibial vessel if we could because of heel ulcers.

You talk about not having weightbearing for 2 to 7 days. Is that because of the bypass or the ulcer?

You do a lot of bypasses for rest pain. Very few of our patients have rest pain because of their diabetic neuropathic feet.

And finally, we have, in this country, an amputation rate that I think is a national problem. Why are not we making an impact on that amputation rate if these operations are available?

Dr Pomposelli. Thank you, Dr Andros. We use MRA for diagnostic evaluation, but quite infrequently. We still rely mostly on intraarterial digital subtraction angiography. We limit the use of MRA to those patients in whom there is some strong contraindication to contrast.

Our experience has been that plantar artery bypass has a different outcome from pedal bypass, which is why they are not included here. We have worse results with that procedure and avoid it whenever possible. The plantar artery may be a poorer outflow tract. Far more often, the dorsalis pedis is patent or a better artery. Dr Scott Burcelli analyzed our results with pedal bypass and demonstrated that healing occurred in about 80% of patients with heel ulcers. Very extensive heel ulcers did not heal, although many did even though the anterior circulation via the pedal artery was the pronciple source of blood supply.

We restrict weightbearing to try to decrease the amount of perioperative swelling. On the average, absolute non-weight bearing is maintained for 2 days, but longer periods of non-weight bearing are maintained in patients with plantar ulcers or open foot wounds or for other reasons.

Rest pain is an indication for pedal bypass in some patients with diabetes. It is infrequent, and it was not, I think, a large percentage of patients. Usually we extend bypass to the dorsalis pedis artery in this circumstance because there is no other outflow target available.

Major amputation remains a significant complication of diabetes mellitus. While some are probably unavoidable, we continue to feel that many of those done for ischemia result from undo pessimism due to misconceptions such as small vessel disease. If nothing else, this paper demonstrates that arterial reconstruction is possible and works well in most patients with ischemic foot complications of diabetes mellitus. All should be evaluated for bypass prior to amputation.

Dr Bruce M. Elliott (Charleston, SC). All too frequently the patient requiring limb salvage presents with limited acceptable targets for bypass, and they often distill down to a choice between the dorsalis pedis or the peroneal as the only acceptable targets. Under what circumstances would you actually prefer to use the peroneal as your target for bypass? And in patients with established forefoot gangrene, has bypass, in your experience, to targets other than the pedal vessel resulted in comparable foot salvage?

Dr Pomposelli. We perform dorsalis pedis bypass frequently in preference to the peroneal bypass. Our goal with tissue loss in the foot is to try to restore a palpable foot pulse. If a femoral-popliteal or a tibial bypass will do achieve that goal, we will not do a dorsalis pedis graft. If the dorsalis pedis graft is a poor quality vessel on the arteriogram, if there is extensive forefoot infection or gangrene, especially where we might do the anastomosis, we will not do a pedal graft. If we do not have adequate venous conduit to reach to the foot, we will look for another suitable more proximal outflow target. In that case, oftentimes a peroneal may be the only other alternative and we will bypass to the peroneal. Pedal bypass is also a very poor operation for claudication. If the only choice was

pedal or peroneal, I would definitely bypass the peroneal in that situation.

Dr Peter R. F. Bell (Leicester, United Kingdom). Just three questions. As far as inflow is concerned from low-down takeoffs, do you eyeball it or how do you measure the adequate inflow?

Secondly, do you do the amputation of the toes, or whatever, at the same time as the procedure?

And thirdly, do you use any long-term anticoagulation at all?

Dr Pomposelli. Usually the arteriogram will demonstrate whether or not the superficial femoral artery is reasonable. If there is any question, we will measure pressure at the area of the proximal anastomosis in the operating room and compare it with the radial arterial pressure. We consider a gradient of less than 5 to be insignificant. If conduit is very limited and we are committed to a pedal bypass, we may accept more disease, or in some cases when a popliteal artery segment is patent, we will perform an above-knee fem-pop with prosthetic graft and then the pedal bypass with vein in sequence.

Minor amputation at the time of bypass is a matter of individual preference. I do it infrequently; others in our division do it regularly.

These patients are not routinely anticoagulated with warfarin. The majority of them are on aspirin, and occasionally some receive another antiplatelet agent.